(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 738 731 B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
28.11.2001 Bulletin 2001/48

(51) Int Cl.[7]: **C07F 7/14**

(21) Application number: **96302476.5**

(22) Date of filing: **09.04.1996**

(54) Alcohols and silated alcohols as accelerators for hydrosilation

Alkohole und sililierte Alkohole als Beschleuniger für Hydrosilylierung

Alcools et alcools silylé comme accélérateur pour l'hydrosilylation

(84) Designated Contracting States:
DE FR GB

(30) Priority: **17.04.1995 US 422470**

(43) Date of publication of application:
23.10.1996 Bulletin 1996/43

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Description

[0001] The present invention is a hydrosilation process where a silicon hydride is contacted with an unsaturated reactant in the presence of a platinum catalyst and with an accelerator selected from the group consisting of tertiary alcohols, silated tertiary alcohols, benzyl alcohol and silated benzyl alcohol. The accelerators are especially useful for the hydrosilation of unsaturated reactants where the unsaturation is in the internal portion of the reactant's structure, for example, as in cyclopentene and cyclohexene. The accelerators are believed to be effective in the presence or absence of oxygen.

[0002] It is known in the art to produce organosilicon compounds by reacting a silicon hydride containing compound with an unsaturated organic compound in the presence of a catalyst. This reaction is typically referred to as hydrosilation or hydrosilylation. Typically, the catalyst is platinum metal on a support, a platinum compound generally in a solvent or a platinum complex.

[0003] The general prior art is represented by US-As 2,823,218 and 3,220,972.

[0004] EPA 0 460 589 relates to a method for the preparation of cyclopentyl trichlorosilane which comprises heating a reaction mixture of trichlorosilane, cyclopentene and a chlorine-deficient chloroplatinic acid catalyst to a temperature above the boiling point of the reaction mixture.

[0005] A major problem known in the art for hydrosilation reactions is the deactivation of catalyst prior to completion of the reaction. One method for catalyst reactivation has been to expose the reaction mixture to oxygen. For example, US-A 4,578,497 describes the use of an oxygenated platinum containing catalyst for use in hydrosilating alkylsilanes. Likewise, US-A 5,359,111 discloses a method for controlling hydrosilation reaction mixtures by controlling the solution concentration of oxygen in the reaction mixture, relative to the concentration of platinum present.

[0006] Further, US-A 5,424,470 claims the use of unsaturated ketones as accelerators for hydrosilation reactions.

[0007] In addition to deactivation, hydrosilation processes of the art are not particularly effective in hydrosilating internal unsaturated bonds in organic molecules. We have unexpectedly found that tertiary alcohols, silated tertiary alcohols, benzyl alcohol and silated benzyl alcohol will act as accelerators for platinum catalyzed hydrosilation processes. These accelerators improve yield of the process in the presence, or absence, of oxygen and are particularly effective in facilitating the hydrosilation of internal unsaturated bonds of organic molecules.

[0008] The present invention is a hydrosilation process where a silicon hydride is contacted with an unsaturated reactant in the presence of a platinum catalyst and with an accelerator. The hydrosilation process comprises contacting (A) a silicon hydride described by formula $R^1_aH_bSiX_{4-a-b}$ (1), where each R^1 is independently selected from a group consisting of alkyls comprising one to 20 carbon atoms, cycloalkyls comprising four to 12 carbon atoms and aryls; each X is independently selected from halogen atom or organooxy radicals described by formula $-OR^1$, where R^1 is as previously described, a=0 to 3, b=1 to 3 and a+b=1 to 4; and (B) an unsaturated reactant selected from a group consisting of (i) substituted and unsubstituted unsaturated organic compounds, (ii) silicon compounds comprising substituted or unsubstituted unsaturated organic substituents and (iii) mixtures of (i) and (ii); in the presence of a platinum catalyst selected from platinum compounds or platinum complexes and an accelerator selected from the group consisting of tertiary alcohols described by formula R^2_3COH (2), silated tertiary alcohols described by formula $(R^2_3CO)_eSiR^1_cH_dX_{4-c-d-e}$ (3), benzyl alcohol and silated benzyl alcohol described by formula $\{(C_6H_5)CH_2O\}_fSiR^1_cH_dX_{4-c-d-f}$ (4); where R^1 and X are as previously described, each R^2 is independently selected from straight-chain alkyls comprising one to 20 carbon atoms, c=0 to 3, d=0 to 3, c+d=0 to 3, e=1 to 4 and f=1 to 4.

[0009] The contacting of the silicon hydride with the unsaturated reactant is effected in standard type reactors for conducting hydrosilation processes. The contact of reactants and subsequent reaction may be run as a continuous, semi-continuous or batch reaction.

[0010] Silicon hydrides which are useful in the present process are described by formula (1), where each R^1 is independently selected from a group consisting of alkyls comprising one to 20 carbon atoms, cycloalkyls comprising four to 12 carbon atoms and aryls; a=0 to 3, b=1 to 3 and a+b=1 to 4.

[0011] In formula (1), it is preferred that each R^1 be independently selected from a group consisting of alkyls comprising one to six carbon atoms. Even more preferred is when each R^1 is methyl.

[0012] In formula 1, each X is independently selected from halogen atom or organooxy radicals described by formula $-OR^1$, where R^1 is as previously described. Preferred is when X is chlorine.

[0013] Examples of silicon hydrides described by formula (1) which are useful in the present process include trimethylsilane, dimethylsilane, triethylsilane, dichlorosilane, trichlorosilane, methyldichlorosilane, dimethylchlorosilane, ethyldichlorosilane, cyclopentyldichlorosilane, methylphenylchlorosilane, (3,3,3-trifluoropropyl)dichlorosilane and methylmethoxychlorosilane. Examples of preferred silicon hydrides of formula (1) include methyldichlorosilane and dichlorosilane.

[0014] The silicon hydride is contacted with an unsaturated reactant selected from a group consisting of (i) substituted and unsubstituted unsaturated organic compounds, (ii) silicon compounds comprising substituted and unsubstituted unsaturated organic substituents and (iii) mixtures of (i) and (ii). For this invention, "unsaturated" means that the com-

pound contains at least one carbon-carbon double bond.

[0015] More specific examples of the unsaturated reactants useful in our process include unsubstituted cycloalkene compounds comprising at least four carbon atoms, substituted cycloalkene compounds comprising at least four carbon atoms, linear alkene compounds comprising two to 30 carbon atoms, branched alkene compounds comprising four to 30 carbon atoms and mixtures of two or more of any of the above compounds.

[0016] The substituted and unsubstituted cycloalkene compounds useful in the present process are those containing one or more unsaturated carbon-carbon bonds in the ring. The unsubstituted cycloalkene compounds are, for example, cyclobutene, cyclopentene, cyclohexene, cycloheptene, cyclooctene, cyclopentadiene, 1,3-cyclohexadiene and 1,3,5-cycloheptatriene. Substituted unsaturated compounds include, for example, 3-methylcyclopentene, 3-chlorocyclobutene, 4-phenylcyclohexene and 3-methylcyclopentadiene. The preferred cycloalkene compounds are cyclohexene and cyclopentene, with cyclohexene being the most preferred.

[0017] Other unsaturated organic compounds useful in this process are linear and branched alkenyl compounds including, for example, compounds with terminal unsaturation such as 1-hexene and 1,5-hexadiene, compounds with internal unsaturation such as trans-2-hexene and unsaturated aryl containing compounds such as styrene or α-methylstyrene.

[0018] The unsaturated reactants may also comprise halogen, oxygen in the form of acids, anhydrides, alcohols, esters and ethers; and nitrogen. Two or more of the above described unsaturated organic compounds may also be used in the present process.

[0019] The unsaturated organic compounds comprising halogen include, for example, vinyl chloride, allyl chloride, allyl bromide, allyl iodide, methallyl chloride, trichloroethylene, tetrachloroethylene, tetrafluoroethylene, chloroprene, vinylidene chloride and dichlorostyrene.

[0020] Suitable unsaturated organic compounds comprising oxygen include, for example, ethers such as allyl and vinyl ethers; alcohols such as allyl alcohol (vinyl carbinol), methylvinylcarbinol and ethynyldimethylcarbinol; acids such as acrylic, methacrylic, vinylacetic, oleic, sorbic and linolenic; and esters such as vinyl acetate, allyl acetate, butenyl acetate, allyl stearate, methylacrylate, ethyl-crotonate, diallyl succinate and diallyl phthalate. Suitable nitrogen containing unsaturated organic compounds include, for example, indigo, indole, acrylonitrile and allyl cyanide.

[0021] Specifically included within the definition of unsaturated organic compounds are those substituted by organofunctional moieties such as $CH_2=CHCH_2OC(O)C(CH_3)=CH_2$, $CH_2=CHCH_2NHCH_2CH_2NH_2$, $CH_2=CHCH_2NH_2$,

$$CH_2=CHCH_2OCH_2\underset{\diagdown\; O \;\diagup}{CH-CCH_2},$$

$CH_2=CHCH_2SH$, $CH_2=CHSi\{O(CH_2)_2OCH_3\}_3$ and $CH_2=CHCH_2N(HCl)HCH_2CH_2NHCH_2(C_6H_4)CH=CH_2$.

[0022] The unsaturated organic compound is a silicon compound comprising substituted and unsubstituted organic substituents as described by, for example, formulas $(CH_2=CH(CH_2)_g)_hR^1_iSi(OR^1)_{4-h-i}$ and $(CH_2=CH(CH_2)_g)_hR^1_iSiCl_{4-h-i}$, where R^1 is as previously described, g=0 to 12, h=1 to 3, i=0 to 3 and h+i=1 to 4.

[0023] Prior to contact of the silicon hydride with the unsaturated reactant, it may be preferable to treat or purify the unsaturated reactant. Useful methods are those known in the art for treating or purifying unsaturated organic compounds and include distillation and treatment with an adsorbent such as activated alumina or molecular sieves.

[0024] The relative amounts of silicon hydride and unsaturated reactant used in our process can be varied within wide limits. Although one unsaturated carbon-carbon linkage per silicon-bonded hydrogen atom is stoichiometric, there is no requirement that the process be run under stoichiometric conditions. Generally, it is preferred that the process be run with a stoichiometric excess of silicon hydride. Preferred is when the process is run with 0.1 to ten percent stoichiometric excess of silicon hydride. However, for safety reasons, it may be preferred to run the process with an excess of unsaturated reactant, for example, when the silicon hydride is dichlorosilane.

[0025] The silicon hydride and unsaturated reactant are contacted in the presence of a platinum catalyst selected from platinum compounds or platinum complexes. Any platinum containing material which effects the reaction between the silicon hydride and an unsaturated carbon-carbon bond of the unsaturated organic compound is useful in this invention. Examples of useful platinum catalysts are described in US-As 4,578,497; 3,220,972 and 2,823,218.

[0026] The platinum catalyst can be, for example, chloroplatinic acid, chloroplatinic acid hexahydrate, Karstedt's catalyst (i.e. a complex of chloroplatinic acid with sym-divinyltetramethyldisiloxane), dichlorobis(tri-phenylphosphine) platinum(II), cis-dichlorobis(acetonitrile)platinum(II), dicarbonyldichloroplatinum(II), platinum chloride and platinum oxide.

[0027] A preferred platinum catalyst is selected from the group consisting of chloroplatinic acid, chloroplatinic acid hexahydrate and platinum vinylsiloxane complexes such as a neutralized complex of chloroplatinic acid or platinum

dichloride with sym-divinyltetramethyldisiloxane.

[0028] Generally, those concentrations of platinum catalyst which provide one mole of platinum per billion moles of unsaturated carbon-carbon bonds added to the process by the unsaturated reactant is useful in the present process. Concentrations of platinum catalyst providing as high as one mole of platinum per one thousand moles of unsaturated carbon-carbon bonds added by the unsaturated reactant may be useful. Higher concentrations of platinum may be used if desired. A preferred concentration of platinum catalyst is that providing one to 1000 moles of platinum per 1×10^6 moles of unsaturated carbon-carbon bonds.

[0029] The platinum catalyst may be dissolved in a solvent for ease of handling and to facilitate measuring the small amounts typically needed. Suitable solvents include, for example, non-polar hydrocarbon solvents such as benzene, toluene and xylene and polar solvents such as alcohols, ketones, glycols and esters.

[0030] The present process is carried out in the presence of an accelerator selected from a group consisting of benzyl alcohol and silated benzyl alcohol, tertiary alcohols and silated tertiary alcohols as described by formulas (2) through (4). In the formulas, each substituent R^2 is independently selected from straight-chain alkyls comprising one to 20 carbon atoms. The substituent R^2 can be, for example, methyl, ethyl, propyl, hexyl and nonadecyl. Preferred is when R^2 is methyl. In formulas (3) and (4), each R^1 is independently selected from a group consisting of alkyls comprising one to 20 carbon atoms, cycloalkyls comprising four to 12 carbon atoms and aryls. Thus, it is preferred that R^1 be methyl.

[0031] In the silated tertiary alcohols described by formula (3) and the silated benzyl alcohol described by formula (4), c has a value of zero to three, d has a value of zero to three and c plus d has a value of zero to three. In formula (3), e has a value of one to four. Preferred is when e has a value of one. In formula (4), f has a value of one to 4. Preferred is when f has a value of one.

[0032] In formulas (3) and (4), each X is independently selected from halogen atom or organooxy radicals described by formula $-OR^1$, where R^1 is as previously described. Preferred is when X is a chlorine atom.

[0033] A preferred accelerator for use in our claimed process is selected from tertiary butyl alcohol or benzyl alcohol.

[0034] An effective concentration of the accelerator is added to the present process, where an effective concentration is one that facilitates initiation of the reaction between the silicon hydride and the unsaturated organic compound, accelerates the rate of the reaction or reduces loss of reactivity of the catalyst in the process. A useful effective concentration of the accelerator is generally within a range of 0.01 to 20 weight percent of the weight of the unsaturated reactant. Preferred is when the accelerator is 0.1 to ten weight percent of the weight of the unsaturated reactant. The accelerator is added to the process as a pre-mix with the platinum catalyst or is added separately.

[0035] The temperature at which the present process is conducted is generally within a range of -10°C. to 220°C. It is preferred to conduct our process at a temperature of 15°C. to 170°C. The most preferred temperature for the process is within a range of 30°C. to 150°C.

Example 1

[0036] A variety of alcohols were evaluated for their ability to accelerate the reaction of methydichlorbsilane with cyclohexene in the presence of a platinum catalyst.

[0037] A stock mixture was prepared in an argon purged and blanketed bottle. The stock mixture comprised four molar percent excess of methyldichlorosilane in cyclohexene which had been treated with 13X molecular sieves. Then, 3.7×10^{-5} to 6×10^{-6} moles of platinum, as a platinum divinylsiloxane complex, per mole of cyclohexene was added to the stock mixture. Aliquots of this catalyzed stock solution were then transferred to argon-purged glass tubes which contained alcohols as described in Table 1 at a concentration of one weight percent of alcohol per total cyclohexene added to the tube. The tubes were heat sealed under argon, purged and heated at 80°C. for three hours. Thereafter, the tubes were cooled and the contents analyzed by gas chromatography using a thermal conductivity detector (GC-TC). The results of this analysis are reported in Table 1 as the normalized area percent of methyl(cyclohexyl)dichlorosilane $Me(C_6H_{11})SiCl_2$ under the GC-TC trace minus the area of the cyclohexene as 100 percent. The results are presented as the mean value of the number of runs provided in parenthesis.

TABLE 1

Alcohols as Accelerators For Platinum Catalyzed Addition of $MeHSiCl_2$ to Cyclohexene	
Type Alcohol	Area% $Me(C_6H_{11})SiCl_2$
None*	42.0 (5)
Benzyl	90.2 (3)
Tertiary Butyl	88.0 (2)

*comparative tests

TABLE 1 (continued)

Alcohols as Accelerators For Platinum Catalyzed Addition of $MeHSiCl_2$ to Cyclohexene	
Type Alcohol	Area% $Me(C_6H_{11})SiCl_2$
Hexyl*	5.5 (2)
Isopropyl*	6.4 (2)
2-Ethyl Hexanol*	9.1 (1)

*comparative tests

Example 2

[0038] The ability of tertiary butyl alcohol to accelerate the reaction of dichlorosilane with cyclopentene in the presence of a platinum catalyst was evaluated.

[0039] A stock mixture comprising 14.2 weight percent of dichlorosilane in cyclopentene was prepared in an argon purged and blanketed bottle. Aliquots of this stock mixture were then transferred to argon purged glass tubes which contained a platinum divinylsiloxane complex providing a concentration of 7×10^{-4} moles of platinum per mole of dichlorosilane. Tertiary butyl alcohol sufficient to provide one weight percent based on the total mass was then added to the tubes. The tubes were heat sealed under an argon blanket and then heated at temperatures indicated in Table 2. After the end of times indicated in Table 2, the tubes were cooled and the contents analyzed by GC-TC. The results of this analysis are reported in Table 2 as the normalized area percent of cyclopentyldichlorosilane ($CpHSiCl_2$) and dicyclopentyldichlorosilane (Cp_2SiCl_2) under the GC-TC trace minus the area of the cyclopentene as 100 percent.

TABLE 2

Tertiary Butyl Alcohol as Accelerator For Platinum Catalyzed Addition of Dichlorosilane to Cyclopentene				
Type Alcohol	Time (Min)	Temp. (°C.)	Area% $CpHSiCl_2$	Area% Cp_2SiCl_2
None	90	120	76.7	0
None	30	25	13.8	0
None	195	25	40.9	0
t-Butyl	105	25	72.9	0
t-Butyl	40	25	72.6	0
t-Butyl	60	120	60.4	1

Claims

1. A hydrosilation process comprising contacting

   (A) a silicon hydride described by formula $R^1_aH_bSiX_{4-a-b}$, where each R^1 is independently selected from a group consisting of alkyls comprising one to 20 carbon atoms, cycloalkyls comprising four to 12 carbon atoms and aryls; each X is independently selected from halogen atom or organooxy radicals described by formula $-OR^1$, where R^1 is as previously described, a=0 to 3, b=1 to 3 and a+b=1 to 4; and
   (B) an unsaturated reactant selected from a group consisting of (i) substituted and unsubstituted unsaturated organic compounds, (ii) silicon compounds comprising substituted or unsubstituted unsaturated organic substituents and (iii) mixtures of (i) and (ii); in the presence of a platinum catalyst selected from platinum compounds or platinum complexes and an accelerator selected from a group consisting of tertiary alcohols described by formula R^2_3COH, silated tertiary alcohols described by formula $(R^2_3CO)_eSiR^1_cH_dX_{4-c-d-e}$, benzyl alcohol and silated benzyl alcohol described by formula $\{(C_6H_5)CH_2O\}_fSiR^1_cH_dX_{4-c-d-f}$; where R^1 and X are as previously described, each R^2 is independently selected from straight-chain alkyls comprising one to 20 carbon atoms, c=0 to 3, d=0 to 3, c+d=0 to 3, e=1 to 4 and f=1 to 4.

2. The process of claim 1 where the silicon hydride is selected from methyldichlorosilane or dichlorosilane.

3. The process of claim 1 where the unsaturated reactant is selected from cyclohexene or cyclopentene.

4. The process of claim 1 where the process is run with 0.1 to ten percent stoichiometric excess of silicon hydride in

respect to unsaturated carbon-carbon linkages of the unsaturated reactant.

5. The process of claim 1 where the concentration of platinum catalyst provides one to 1000 moles of platinum per 1×10^6 moles of unsaturated carbon-carbon bonds provided by the unsaturated reactant (B).

6. The process of claim 1 where the accelerator is selected from tertiary butyl alcohol or benzyl alcohol.

7. The process of claim 1 where concentration of the accelerator is within a range of 0.01 to 20 weight percent of the unsaturated reactant.

8. The process of claim 1 where contact of the silicon hydride with the unsaturated reactant is effected at a temperature within a range of -10°C. to 220°C.

Patentansprüche

1. Hydrosilylierungverfahren, umfassend Inberührungbringen von

   (A) einem Siliciumhydrid, das durch die Formel $R^1_aH_bSiX_{4-a-b}$ beschrieben ist, worin jedes R^1 unabhängig voneinander ausgewählt ist aus einer Gruppe bestehend aus Alkylgruppen mit 1 bis 20 Kohlenstoffatomen, Cycloalkylgruppen mit 4 bis 12 Kohlenstoffatomen und Arylgruppen; jedes X unabhängig voneinander ausgewählt ist aus einem Halogenatom oder Organooxyresten, beschrieben durch die Formel $-OR^1$, worin R^1 wie zuvor definiert ist, a gleich 0 bis 3 ist, b gleich 1 bis 3 ist und a+b gleich 1 bis 4 ist; und

   (B) einem ungesättigten Reaktanten, ausgewählt aus einer Gruppe bestehend aus (i) substituierten und unsubstituierten ungesättigten organischen Verbindungen, (ii) Siliciumverbindungen, die substituierte oder unsubstituierte ungesättigte organische Substituenten enthalten, und (iii) Mischungen von (i) und (ii); in Gegenwart eines Platinkatalysators, ausgewählt aus Platinverbindungen oder Platinkomplexen, und einem Beschleuniger, ausgewählt aus einer Gruppe bestehend aus tertiären Alkoholen, beschrieben durch die Formel R^2_3COH, silylierten tertiären Alkoholen, beschrieben durch die Formel $(R^2_3CO)_eSiR^1_cH_dX_{4-c-d-e}$, Benzylalkohol und silyliertem Benzylalkohol, beschrieben durch die Formel $\{(C_6H_5)CH_2O\}_fSiR^1_cH_dX_{4-c-d-f}$, worin R^1 und X wie zuvor beschrieben sind, jedes R^2 unabhängig voneinander ausgewählt ist aus gradkettigen Alkylgruppen mit 1 bis 20 Kohlenstoffatomen, c gleich 0 bis 3 ist, d gleich 0 bis 3 ist, c +d gleich 0 bis 3 ist, e gleich 1 bis 4 ist und f gleich 1 bis 4 ist.

2. Verfahren nach Anspruch 1, wobei das Siliciumhydrid aus Methyldichlorsilan oder Dichlorsilan ausgewählt ist.

3. Verfahren nach Anspruch 1, wobei der ungesättigte Reaktant aus Cyclohexen oder Cyclopenten ausgewählt ist.

4. Verfahren nach Anspruch 1, wobei das Verfahren mit einem 0,1 bis 10%igen stöchiometrischen Überschuss von Siliciumhydrid in bezug auf ungesättigte Kohlenstoff-Kohlenstoff-Verknüpfungen des ungesättigten Reaktanten durchgeführt wird.

5. Verfahren nach Anspruch 1, wobei die Konzentration des Platinkatalysators 1 bis 1000 Mol Platin pro 1×10^6 Mol ungesättigter Kohlenstoff-Kohlenstoff-Bindungen, die von dem ungesättigten Reaktanten (B) geliefert werden, zur Verfügung stellt.

6. Verfahren nach Anspruch 1, wobei der Beschleuniger aus tertiärem Butylalkohol oder Benzylalkohol ausgewählt ist.

7. Verfahren nach Anspruch 1, wobei die Konzentration des Beschleunigers innerhalb eines Bereichs von 0.01 bis 20 Gew.-% des ungesättigten Reaktanten liegt.

8. Verfahren nach Anspruch 1, wobei der Kontakt des Siliciumhydrids mit dem ungesättigten Reaktanten bei einer Temperatur innerhalb eines Bereichs von -10°C bis 220°C bewirkt wird.

Revendications

1. Procédé d'hydrosilylation comprenant la mise en contact de (A) un hydrure de silicium décrit par la formule $R^1_aH_bSiX_{4-a-b}$, dans laquelle chaque R^1 est indépendamment sélectionné dans un groupe constitué par les alkyles comprenant un à 20 atomes de carbone, les cycloalkyles comprenant quatre à 12 atomes de carbone et les aryles ; chaque X est indépendamment sélectionné parmi un atome d'halogène ou les radicaux organooxy décrits par la formule $-OR^1$, dans laquelle R^1 est comme décrit précédemment, a = 0 à 3, b = 1 à 3 et a + b = 1 à 4 ; et (B) un réactif insaturé sélectionné dans un groupe constitué par (i) les composés organiques insaturés, substitués et non substitués, (ii) les composés de silicium comprenant des substituants organiques insaturés, substitués ou non substitués et (iii) les mélanges de (i) et (ii) ; en présence d'un catalyseur de platine sélectionné parmi des composés de platine ou des complexes de platine et un accélérateur sélectionné dans un groupe constitué par les alcools tertiaires décrits par la formule R^2_3COH, les alcools tertiaires silylés décrits par la formule $(R^2_3CO)_eSiR^1_cH_dX_{4-c-d-e}$, l'alcool benzylique et l'alcool benzylique silylé décrit par la formule $\{(C_6H_5)CH_2O\}_fSiR^1_cH_dX_{4-c-d-f}$; dans lesquelles R^1 et X sont comme décrit précédemment, chaque R^2 est indépendamment sélectionné parmi les alkyles à chaîne droite comprenant un à 20 atomes de carbone, c = 0 à 3, d = 0 à 3, c + d = 0 à 3, e = 1 à 4 et f = 1 à 4.

2. Procédé selon la revendication 1, dans lequel l'hydrure de silicium est sélectionné parmi le méthyldichlorosilane ou le dichlorosilane.

3. Procédé selon la revendication 1, dans lequel le réactif insaturé est sélectionné parmi le cyclohexène ou le cyclopentène.

4. Procédé selon la revendication 1, dans lequel le procédé est conduit avec 0,1 à 10 % d'excès stoechiométrique d'hydrure de silicium par rapport aux liaisons carbone-carbone insaturées du réactif insaturé.

5. Procédé selon la revendication 1, dans lequel la concentration de catalyseur de platine apporte une à 1000 moles de platine pour 1 x 10^6 moles de liaisons carbone-carbone insaturées apportées par le réactif insaturé (B).

6. Procédé selon la revendication 1 dans lequel l'accélérateur est sélectionné parmi l'alcool tertio-butylique ou l'alcool benzylique.

7. Procédé selon la revendication 1, dans lequel la concentration de l'accélérateur est dans un intervalle de 0,01 à 20 % en poids du réactif insaturé.

8. Procédé selon la revendication 1, dans lequel le contact de l'hydrure de silicium avec le réactif insaturé est réalisé à une température dans un intervalle de -10°C à 220°C.

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